Space Weather Technical Forecast

Issued on Tuesday, 21 December 2021 at 13:25 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Slight chance of G1/Minor Storms day 1 (21st), and on Days 3 and 4 (23rd and 24th). Occasional M-class flares likely throughout. Chance of Active electron fluence developing later in the period.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar Activity has been Moderate over the past 24 hours, with a number of C-class X-ray flares observed, and two M-class flares at 21/0750 UTC and 21/1144 UTC. A previous M class flare at 20/1136UTC, from an active region in the southern hemisphere near the centre disc, produced a weak coronal mass ejection (CME). Analysis of this CME indicates an arrival time on day 3 (23 Dec).

There are currently 9 sunspots on the visible disc. The most prominent is a series of three regions in the southern central disc: AR2907 remains the most complex, currently classified as a Dai/Beta-Gamma. AR2908 was the likely source for the M-class flare on the 20th Dec, but this continues to show some decay and is currently classified Dai/Beta. AR2909 also decayed, and is now classified Cso / Beta. All other regions are either small unipolar or bipolar regions. The 2 M-class flares on the 21 Dec originated from a region beyond the eastern limb. These may have generated CMEs, which are unlikely to be Earth-bound given the location, but they will be analysed when satellite imagery becomes available. No other CMEs were observed in available imagery.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by the DSCOVR satellite at L1, has been elevated throughout, starting the period at 530km/s, rising to 600-650km/s by the end of the period. This is as a result of a high speed stream from CH35 and CH36. Density has generally been average or above average, with a peak of 27 ppcc at 20/2224 UTC. The Interplanetary Magnetic Field Strength (IMF), Bt has been between 4nT and 7nT throughout. The all important north-south component (Bz) ranged from +5nT to -7nT, with its southward (negative) peak at the start of the period. The phi angle was predominately negative throughout (towards the Sun).

Geomagnetic activity has been Quiet to Active (Kp 1-4).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at Background levels. The high energy electron flux (greater than 2 MeV) was at mainly Background levels, but peaked at moderate during the diurnal maximum. The associated 24-hour integrated fluence remained well below the Active threshold and stable. A fluence of 4.74e6 was observed at 21/1200 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be predominantly Moderate, with further C-class flares and occasional M-class flares likely - mainly from AR2907, AR2908 and AR2909, and also the new region beyond the eastern limb. There are also a number of filaments visible in H-alpha imagery and whilst currently stable, they will need monitoring for any potential lift off.

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Solar Wind / Geomagnetic Activity: A coronal mass ejection (CME) seen in SOHO/Lasco imagery at 20/1236UTC as a result of the aforementioned M-class flare from AR2908 (southern centre disc) has been analysed and is forecast to arrive at Earth during day 3 (23rd Dec). Elevated, possibly strong, solar winds are expected to persist through days 1 and 2 (21-22 Dec) due to CH36 and CH35, before gradually easing on days 3 and 4 (23-24 Dec) . Geomagnetic activity is forecast to be Quiet to Unsettled through days 1-2 (21-22 Dec), with Active intervals possible. These are most likely to occur early on day 1 (21 Dec) during the transition to CH35, when there is a slight chance of a G1 / Minor Storm. On days 3 and 4 (23-24 Dec), geomagnetic activity is likely to become mostly Quiet, however, the arrival of the weak CME gives rise to the chance of active intervals, and a slight chance of a G1 / Minor Storm on Day 3 (23 Dec).

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels and below the S1 level, although there is the potential for some increased flux from any flare activity. The high energy electron flux is forecast to be at background at first, but rising days 1-2 (21-22 Dec) due to recent solar wind enhancements from the arrival of the fast wind of CH36. Peak flux is likely to reach High levels (1000 pfu), but brief some drop outs are possible as any further enhancement from CH35 arrives. Persistently high flux is possible by days 3 and 4 (23-24 Dec)., although this may be limited due to the CME arrival. The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold, but there is the chance of rising above on day 2 (22 Dec). Whilst this risk increases through the period, it remains low confidence.

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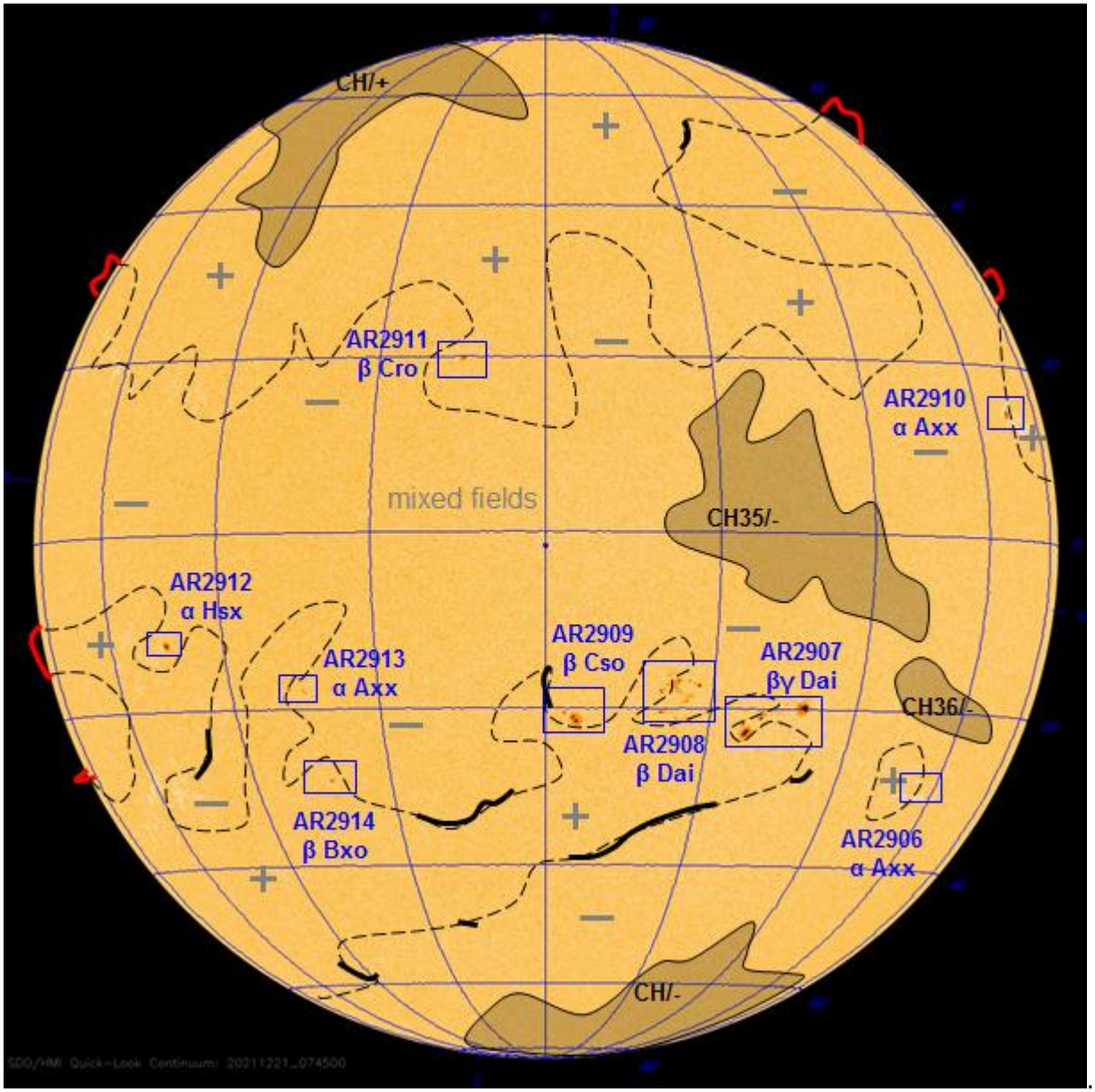
Figure 1. Solar Analysis Valid 21/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Met Office Space Weather Technical Forecast

Geomagnetic Storms:

Earth is connected to the fast wind of CH36, with solar winds currently elevated to strong, currently ranging between 600-640 km/s. Solar winds are likely to remain elevated through days 1-3 (21-22 Dec), with further enhancement coming from CH35. A gradual decline is then expected on day 3 (23 Dec) as coronal hole effects wane. This is supported by enlil and 27-day persistence which shows a fast wind enhancement until day 2 (22 Dec), and then easing. However, analysis of a CME that left the sun on the 20th indicates an arrival time at Earth on day 3 (23 Dec).

Geomagnetic activity is forecast to be Quiet to Unsettled through days 1-2 (21-22 Dec), with Active intervals possible. These are most likely to occur early on day 1 (21 Dec) during the transition to CH35, when there is a slight chance of a G1 / Minor Storm. On days 3 and 4 (23-24 Dec), geomagnetic activity is likely to become mostly Quiet, however, the arrival of the weak CME gives rise to the chance of active intervals, and a slightchance of a G1 / Minor Storm on Day 3 (23 Dec).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	10	20	20
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
20/12/2021 1804 UTC	Partial	AR2908	14S11E	625	23/12/2021 12UTC	Limited shock expected

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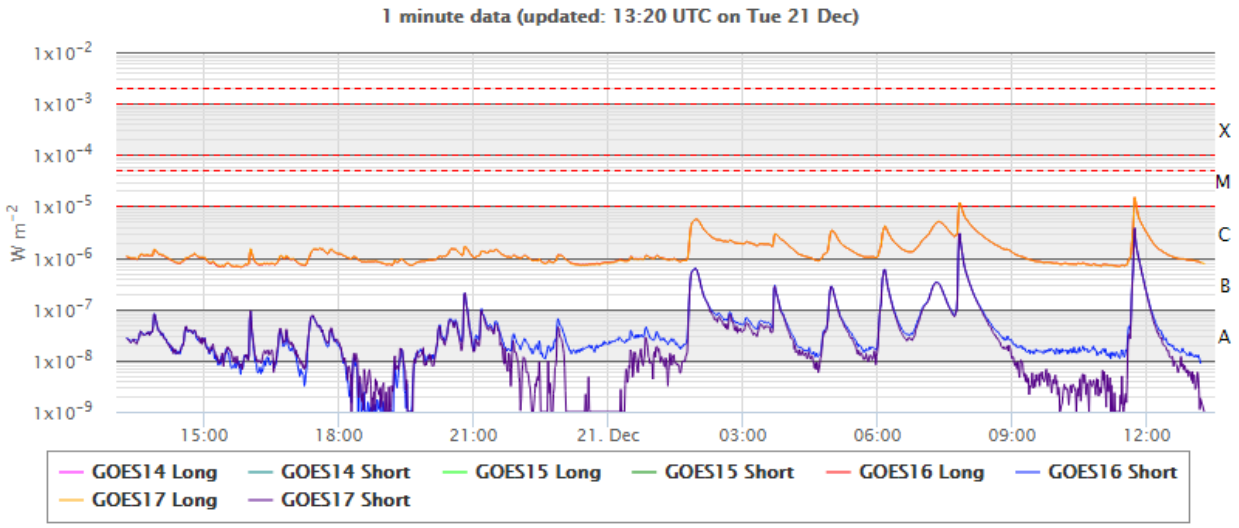
Radio Blackouts - X-Ray Flares:

There are currently nine active sunspot regions on the Earth-facing disc, the most prominent is a series of three regions in the southern central disc: AR2907 remains the most complex, currently classified as a Dai/Beta-Gamma. AR2908 was the likely source for the M-class flare on the 20th Dec, but this continues to show some decay and is currently classified Dai/Beta. AR2909 also decayed, and is now classified Cso / Beta. All other regions are either small unipolar or bipolar regions. The 2 M-class flares on the 21 Dec originated from a region beyond the eastern limb. These may have generated CMEs, which are unlikely to be Earth-bound given the location, but they will be analysed when satellite imagery becomes available.

Solar activity is expected to be predominantly Moderate, with further C-class flares and occasional M-class flares likely - mainly from AR2907, AR2908 and AR2909, and also the new region beyond the eastern limb.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	60	60	60	60
Very Active	R3 to R5 X Class	No	2	2	2	2

Figure 2: X-ray flux as measured by GOES-16. The recent M-class flaring seems to have originated from a sunspot region beyond the east limb.



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Solar Radiation Storms - (High Energy Protons):
The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at Background levels.
Despite the large number of sunspots on the disc, a number of which are now moving into an improved geoeffective location for radiation storms, their small size and generally simple magnetic structure means that proton rich flaring is unlikely. Background levels are expected to persist, with a chance of some small increases from any notable flares that do occur. However, there is only a very slightly above background risk of rising to the S1 alert level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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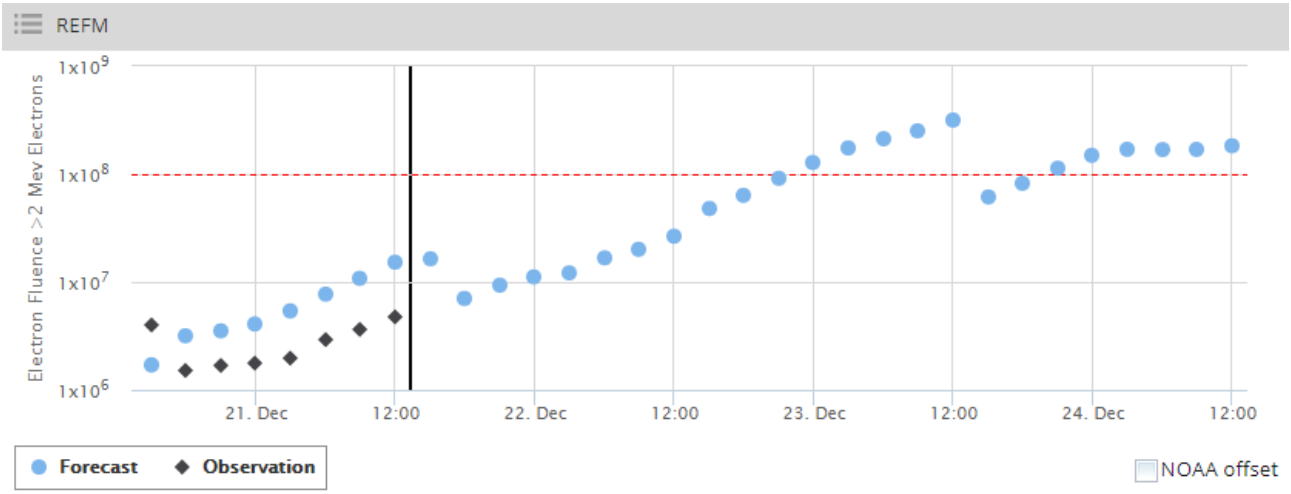
High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2 MeV) electron flux as observed by GOES-16 is currently at background levels. Once the potential geomagnetic activity on day 1 (21 Dec) ease a gradual build of observed flux is likely, peaking at High levels (above 1000 pfu). Further enhancement from any arrival of fast wind from CH35 on day 1 and 2 (21-22 Dec) could bring dropouts to the observed flux, before Moderate to High levels are expected to resume. This enhancement is currently uncertain however, giving low confidence to the forecast by days 3 and 4 (23-24 Dec), which depends on the arrival of a CME.

The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold until day 2 (22 Dec) with a chance of rising above. Whilst this risk increases through the period, it remains low confidence due to uncertainty around the strength of any enhancement from CH35 and a the CME arrival forecast for day 3 (23 Dec). REFM is giving good guidance showing a rising trend for the current solar wind enhancement.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	20	30	40	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 3: REFM showing the predicted electron fluence over the next 3 days. The arrival of the forecast CME on day 3 may limit the increase in fluence.



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